PRELIMINARY PROGRAM
4th Chemical Congress of North America
and 202nd ACS national meeting,
New York City Page 47

JUNE 17, 1991

CHEMICAL & ENGINEERING

NEWS

********** 5-DIGIT 20814
05111790CV1 T K AR6924SL01 0734
CONGRESSIONAL INFO SERV-SRI
SRI ACQUISITIONS
4520 EAST WEST HWY SUITE 800
BETHESDA MD 20814-3389

A C&EN Special Issue

ENERGY

Current issues prompt reassessment of options

Page 18

CHEMICAL & ENGINEERING
NEWS
JUNE 17, 1991

Volume 69, Number 24
CENEAR 69 (24) 1–88
ISSN 0009-2347

News of the Week

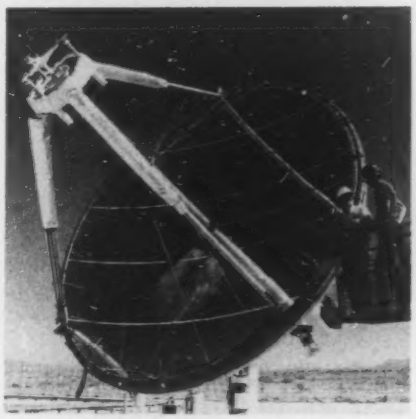
- **East European chemical output plunges as nations restructure for shift to market economy, but prospects are bright in long term for certain nations and chemical sectors.** **Page 4**
- **DuPont is giving $225,000 over three years to Howard University to set a up polymer science program.** **Page 5**
- **CMA begins $6 million national advertising campaign to improve public's image of chemical industry.** **Page 6**
- **House rejects attempts to delete funding for space station and supercollider as it begins working on appropriations bills for fiscal 1992.** **Page 6**
- **With $510,000 award to University of Wisconsin, Eau Claire, Research Corp. launches new program aimed at upgrading selected chemistry and physics departments.** **Page 7**

Cover: Photo by Pictor/Uniphoto Inc.

Letters 2
Editor's Page 3

Concentrates
Business 9
Government 13
Science/Technology 16

The Department
Newscripts 88



ENERGY

Attention is again focused on energy policy and technology options as politicians and the public grapple with environmental and political issues. **Page 18**

Energy Policy

Policymakers must wrestle with the realities of world politics, the need to make environmentally sound decisions, and the difficulties of accommodating the U.S.'s energy-use patterns as they forge an energy strategy for the nation. **Page 20**

Coal

Department of Energy's clean-coal program, which aims to give coal a better image and find environmentally acceptable ways to use it, is key to future utility of this abundant natural resource. **Page 32**

Nuclear

Smaller, standardized nuclear electric power plants under development are designed for incremental generating capacity, simpler licensing, advanced reactor safety. **Page 36**

Solar

Solar generation of electric power has received renewed interest with the sharp fall in costs in the past 20 years for both photovoltaic and solar thermal processes, the two major ways of converting the Sun's energy directly to electricity. **Page 41**

Preliminary Program

4th Chemical Congress of North America and 202nd ACS national meeting in August in New York City offers variety of symposia; listing and highlights of technical sessions, and full general program are included. **Page 47**

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036
Editor: Michael Heylin
Assistant Managing Editors: James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; London: Patricia L. Layman; Washington: Doron Dagani, Lois R. Ember, Bette Hileman, Wilbert C. Lepkowski, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Ann Marie Menting, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Arlene Goldberg-Gist (Head), Rita E. Johnson (Editorial Assistant), Patricia Oates (Administrative Assistant)
News Bureaus: Northeast News Bureau: (201) 906-8300 Marc S. Reisch (Associate Editor), Ann M. Thayer (Associate Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (708) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head), Susan J. Ainsworth, (Associate Editor). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head)
Graphics and Production: Leroy Corcoran (Head). Barbara Fryer (Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing)
Composition Systems Administrator: Vincent L. Parker. **Assistant:** Robin L. Shapiro
Business Manager: Arthur Poulos
Circulation Director: David Schulbaum
ADVISORY BOARD: Dexter F. Baker, George M. Bodner, F. Peter Boer, Will D. Carpenter, Renée G. Ford, Ethan C. Galloway, Louis J. Glunz, Kenneth G. Hancock, Harry S. Hertz, Christopher T. Hill, Kendall N. Houk, Cynthia A. Maryanoff, Linda B. McGown, C. Bradley Moore, George B. Rathmann, David A. Shirley, Peter H. Spitz, Barry M. Trost

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
Robert H. Marks, Director, Publications Division

PUBLISHING BOARD: Jean'ne M. Shreeve *(Chairman); Board of Directors Chairman:* Joseph A. Dixon; *President:* S. Allen Heininger; Richard L. Deming; William P. Jencks; Gary J. Long; and Louis D. Quin

© Copyright 1991, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: ACS, Dept. L-0011, Columbus, Ohio 43268-0011. Correspondence and telephone calls for changes of address, claims for missing issues, subscription orders, status of records and accounts should be directed to: Manager, Member & Subscriber Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (800) 333-9511 or (614) 447-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1991: Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management: CENTCOM LTD.
(For list of offices see page 87)
Office of Ombudsman: (800) ACS-5558, No. 8

LETTERS

Calcium carbonate

This is an interesting historical footnote about the story on calcium carbonate (C&EN, April 29, page 9). In late 1945 or early 1946, I was operating a fluid bed pilot plant for lime burning at New England Lime Co. in North Adams, Mass. At that time New England Lime was making precipitated calcium carbonate from their very high quality lime (made from a stone that was almost marble) and carbonating it with scrubbed combustion gases from the rotary lime kilns.

The product was filtered, dried, bagged, and sold for use in, among other things, cigarette paper and toothpaste. Later, about 1947, Pfizer bought the company. This may have been Pfizer's first entry into the business, but they may have had other production facilities. I doubt that there is anyone still active in Pfizer that was an employee at the time.

Cigarette paper is hardly a growth market, and this may account for its not being mentioned in the C&EN article.

James V. Thompson
ACS Emeritus
Lafayette, Calif.

Adding iron to oceans

I noted, with interest, the recent debate over the merits of fertilizing southern seas with iron to reduce atmospheric carbon dioxide. Sophisticated arguments have been advanced on the kinetics and practicality of the approach (C&EN, Feb. 4, page 29), but comments on the potential impact of iron addition on the community structure have been surprisingly absent.

The low solubility of iron (III) in many environments makes it a precious resource. Competitive advantage can be gained by organisms able to make special complexing agents called siderochromes that solubilize and tie up available iron. Organisms able to recognize and transport these iron complexes into the cell come to dominate the local community. At least one paper [Murphy, T. P., Lean, D. R. S., Nalewajko, C. *Science*, **192** (4242), 900 (1976)] has appeared showing that this phenomenon explains species succession in freshwater algal blooms. It seems likely that similar control occurs in marine systems.

Although it is not surprising that the indiscriminant addition of available iron to an Antarctic marine algal community should cause a rush of growth and activity, alteration of the overall community structure over time could lead to unpredictable ultimate effects. Iron is not just another nutrient present or absent in adequate concentration; it has been identified in the past as one of nature's most active battlegrounds and a key to determining winners and losers in mixed populations.

Thomas R. Jack
Manager, Applied Sciences
Nova Husky Research Corp.
Calgary, Alberta, Canada

Higher level of integrity

I gather from the content of your editorial on the David Baltimore/Margot O'Toole issue (C&EN, April 8, page 3) that you once held those who were called scientists to a higher level of integrity than the public at large.

My own observation after a lifetime of experience is that they are no more veracious than parsons, popes, or presidents. Only open discussion and competition serve as a brake on less than scrupulous scientists.

Charles V. Berger
Western Springs, Ill.

Hooray for Margot O'Toole and Rep. John Dingell! Truth will out! The system works! We all benefit when arrogant crooks are exposed, regardless of who they are and where they are.

From the number of scientists who supported David Baltimore in his impossible position, it would appear that Dingell and his group still have work to do.

Your editorial on humility is good common sense, understood by many who are scientifically illiterate. Too bad this simple truth has escaped Baltimore and his following.

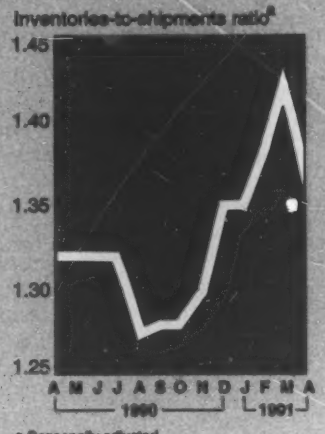
Thomas T. Noland
New Canaan, Conn.

Safety of nuclear power

I feel compelled to respond to the letter of Nancy Adin (C&EN, April 22, page 59). She questions the safety of nuclear power plants on the basis of "how safe is safe." This question should be applied equally to all forms of generating electricity—not just to nuclear. We cannot have a guarantee of absolute safety of nuclear plants. However, the safety of nuclear plants over the 35 years of their existence exceeds the safety of any alternative source of electricity.

Continued on page 87

Inventories/shipments



As a result of increased demand, the shipments-to-inventories ratio for chemicals and allied products fell back to a more normal level in April, according to seasonally adjusted data from the Commerce Department. The government figures show that shipments of chemicals in April rose 5.4% from the previous month after a 3.9% decline in March. On a year-to-year basis, shipments of chemicals and allied products were up 3.0% in April, following an annual decline of 1.2% in March. Inventories of chemicals in April were essentially flat, falling just 0.2% from March, which had been up 1.0% from February. On an annual basis, stocks were up 5.5% in April from the same month a year earlier. In March, inventories had increased 6.3% from March 1990. The result was that the shipments-to-inventories ratio fell to 1.36 in April from a high of 1.43 in March and 1.38 in February. However, the ratio is higher than it had been in April 1990 when it was 1.32.

Amoco, Allied plan fiber pact

Amoco Fabrics & Fibers and Allied Fibers, a division of Allied-Signal, are completing negotiations to form a joint venture to manufacture and market solution-dyed nylon (SDN) for the commercial and residential carpet markets. The companies say that use of SDN yarns, which already account for about 15% of the commercial carpet market, is expected to double in volume by 1995 and triple by the end of the decade when the yarns likely will represent about 40% of the commercial segment. Under the proposed agreement, Amoco will make the yarns at its Bainbridge, Ga., filament yarns plant and Allied will supply the resin as well as market the SDN yarns. Amoco Fibers & Fabrics is a unit of Amoco Chemical.

Du Pont, ConAgra in polylactides venture

A joint venture between Du Pont and ConAgra is developing and planning to market polylactides—polymers made from lactic acid—which have shown biodegradability in laboratory tests. The joint venture, Ecological Chemical Products Co., will develop the polylactide materials from such products as cheese whey and corn. The venture uses proprietary technology to convert these raw materials to high-purity lactic acids, derivatives, and polymers. Commercial quantities of the new polymer material are expected in late 1994. Targeted industries may include paper, printing, packaging, and specialty products.

Enzon to acquire Genex

Enzon, the South Plainfield, N.J.-based biotechnology company, has reached a definitive agreement to acquire Genex, the troubled Gaithersburg, Md.-headquartered protein engineering firm, in a stock swap. Genex has been searching for capital, but has been unsuccessful as a stand-alone company. Reed R. Prior, president and chief executive officer of Genex, says, "This arrangement exemplifies a growing trend whereby cash-poor biotech companies with strong technologies are being acquired by stronger companies looking for complementary technologies and capabilities." Enzon says the acquisition will enable it to expand its product pipeline and strengthen and broaden its technological foundation. The company has agreed, subject to certain limitations, to provide for Genex's interim working capital requirements. The merger is subject to approval by Genex stockholders and is expected to be concluded in September.

Add Exxon to the MTBE list

Exxon is joining the rapidly growing group of companies that are planning units to make methyl *tert*-butyl ether (C&EN, June 10, page 13). Exxon will build a 7000 barrel-per-day unit to produce the gasoline oxygenating agent at its Baton Rouge, La., refinery. The project will take 14 to 18 months to complete, with groundbreaking about six months into this schedule. Cost of the project was not disclosed. Jacobs Engineering will provide engineering and construction services.

RWE-DEA completes acquisition of Vista

The Federal Trade Commission didn't raise any last minute objections and so Hamburg-based RWE-DEA acquired more than 85% of Vista's outstanding shares on June 7 (C&EN, June 10, page 7). Based on the 10.8 million shares it received, RWE-DEA has paid $594 million to acquire its new subsidiary. RWE-DEA will acquire shares not purchased through the tender offer in a subsequent merger at $55 a share. Armin Schram, chairman of RWE-DEA, says the combined companies "can now devote our energies to the business at hand: becoming a more powerful presence in the global chemicals marketplace. We will do so by jointly strengthening our existing marketing efforts while simultaneously expanding into new markets such as the Far East." He also says Vista's corporate headquarters will remain in Houston and that no layoffs or plant closings are planned as a result of the acquisition.

Deltech starts up polystyrene unit in Ohio

Deltech Polymers has started production of prime crystal polystyrene at a newly acquired facility in Troy, Ohio. The unit is rated at an annual capacity of 145 million lb. Deltech bought the 10-year-old plant from Goodsen Polymers in April and has now brought it back on stream a year after it was shut down. No financial details on the startup or cost of the

Coal

In the national energy picture, the Department of Energy's clean-coal program is key to future utility of coal

Joseph Haggin, C&EN Chicago

Coal probably has more "players" than any other energy game. The mining industry, the electric power industry, environmentalists, national and state governments, regional associations, numerous state universities and national laboratories, the major energy companies, and many local jurisdictions all have much at stake in the future performance of coal as a fuel.

Coal is abundant, relatively cheap, and widely distributed. It also is a polluter and has a very bad image. Providing coal with an acceptable image and finding ways to use it within environmental limits is the task of the U.S. Department of Energy's clean-coal program. Most of the players mentioned also have coal development programs, but the clean-coal program is the key to the future utility of coal in the national energy picture.

DOE's general attack in the clean-coal program was outlined recently by Robert H. Gentile, assistant secretary for fossil energy, at an international conference in London. He notes that coal remains a true measure of Earth's collective energy strength. As a part of a "new world order," Gentile calls for a new technological order that will, among other things, permit the use of Earth's most abundant energy source.

The point seems well taken since, as Gentile notes, Earth's population draws nearly a third of its energy needs form coal. Coal generates 44% of the world's electricity and is used in the production of 75% of the world's steel.

Emerging nations of the world use about 30% of the global energy produced, and their consumption is expected to triple in the next 30 years. The imminent consolidation of European markets is another factor in increasing energy competition. EC-92 may be good for Europe, but it will stress the global energy and economic picture still further.

Gentile does not believe that concern over the environment can be used as a valid excuse to limit economic growth, and, consequently, to limit energy use. Neither can it be used as an excuse to deny developing countries the opportunity to improve their living standards. Technology can be developed to accomplish all these things, but it will take time, investment, and the good offices of international associations. Predictably, Gentile believes that the energy strategy of the Bush Administration is sensible because it is based on citizen involvement rather than government intervention and because "we cannot tax ourselves into a better world, but we can innovate."

The clean-coal program has passed several milestones since its inception in 1986. Several demonstration plants recently have been started up, and ground has been broken for others. Gentile foresees the production of motor fuels from coal. The cost of doing this, he says, has been reduced to about $36 per barrel with the prospect of further reductions to about $30 per bbl. Not everyone agrees with that estimate, but it does indicate that technical progress in coal combustion and conversion is being made. And the clean-coal program is a key element in that progress.

The clean-coal program is a joint government-industry cofunded development effort. Its goal is to provide the U.S. with advanced, efficient, and environmentally acceptable coal-consuming technologies. The program began the first of five phases in 1986. Phase I concentrated on new and retrofit applications to increase the use of coal as an energy option. Phase II started the following year and was focused on demonstrating new technologies that can decrease the production of acid rain from coal combustion. Phase III started in 1989 and is dedicated to reducing emissions of sulfur oxides and nitrogen oxides from existing facilities. Phase IV is just getting started (it began in February), and Phase V will begin in March of 1992.

The first three phases in the clean-coal program contained 38 projects, but in December 1990 three of them were canceled—ostensibly for technical reasons but with unfavorable economics playing a decisive role. The remaining 35 projects are still under way, and their completion will permit the sponsors to market the technology that results from the work.

Coal is abundant but has major barriers affecting its use. These are generally acknowledged to be the effects on air quality, the contributions to acid rain formation from the intrinsic sulfur, the contributions to suspected global warming, and the often highly localized pollution from particulate emissions. Coal also figures in the national energy security debate and in the drive to increase industrial competitiveness.

Despite its bad image as an air polluter, coal-burning industries have already spent more than $250 billion to control emissions since 1970. Most of this has been spent by the U.S. electric power industry. As a result, SO_x emissions have dropped dramatically, although

much of the drop is also attributed to the use of lower sulfur coals. A number of particularly troublesome plants have also been taken off stream.

Compliance with the newest SO_x and NO_x regulations will cost the electric power industry about $4 billion to $5 billion annually until the end of the century. Eventually SO_x levels will be capped at the levels of the year 2000, which will be about half the 1980 levels. Permissible NO_x levels in 2000 will be those from the best available devices of the time. Compliance with the acid rain provisions will occur in two phases. The first phase requires that utilities reduce sulfur dioxide to 5 million tons below the 1980 level by the beginning of 1995. In Phase II, a reduction to 10 million tons below the 1980 level will be completed by the end of the century. In addition, NO_x control devices must also be installed on all existing and future generating plants.

A good deal of the concern over pollution from coal-fired power plants is directed at production of carbon dioxide, which is linked to future global warming. Much of the increase in levels of CO_2 in the atmosphere in modern times has been attributed to combustion of fossil fuels and deforestation. In 1986, according to DOE, the U.S. contribution to total global CO_2 emissions was 22%. Electric power generation accounted for 35% of this amount, transportation 30%, industry 24%, and other sources (residential and commercial) the remainder. Hence, it may well be necessary to have suitable technology available to further mitigate the effects. One of the clean-coal program's principal objectives is the reduction of CO_2 emissions.

Unit power costs in the U.S. declined steadily until about 1970, mostly because of the economies of scale. The technology of electricity generation went through a number of incremental improvements, but the basic processes didn't change much. By 1970, some metallurgical limits had been reached, which prevented a further rise in operating temperatures of coal-fired generating plants. Additional incremental improvements would be fewer.

Thereafter, with passage of the Clean Air Act, costs began to rise because of the expense of emissions reduction and control. Furthermore, the act provided some economic incentives to retain existing plants beyond their normal retirement. New plants with added environmental costs would simply cost more than retaining the older ones. Some of these plants are now expected to last up to 60 years, about a third longer than was projected. Eventually new plants will be required, and they will be inherently more expensive. It is now estimated by DOE that about 40% of the capital investment and about 30% of the total cost of a new coal-fired generating plant goes to the mandated environmental controls.

In spite of this, coal remains the fuel of choice for most new plants. About 56% of the power presently generated comes from coal-fired plants. Utility companies in the U.S. consume about 80% of the coal mined. The expectation is that by the end of the century coal will provide about 60% of the electric power generated.

In the mid-1990s, utilities will be confronting two new problems. The first will be aging hardware, the second diminishing reserve capacity. Both problems are directly related to deferring new plants into the indefinite future.

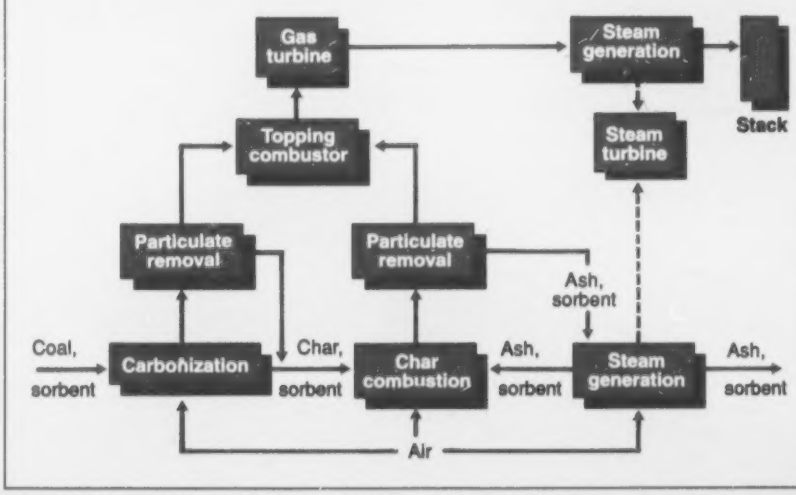
One of the few bright spots in the U.S. energy picture is the abundance of coal reserves. These are estimated by DOE at 268 billion tons. At double present consumption, these reserves are expected to last well into the 21st century and maybe beyond. But however abundant it may be, that coal is expensive to mine, transport, and use in many applications. The coal abundance does give comfort to those concerned with U.S. energy security, although it would be very difficult to do any realistic substitution for other energy sources.

There is a further, not inconsiderable factor in the clean-coal program besides the purely technical. That is the possibility of marketing U.S. coal-consuming technology abroad in the future.

In the clean-coal program, the technology is divided into three categories: preparing the coal for use, using it, and depolluting the products. Combustion is the usual process, although direct conversion to fuels and chemicals is also being considered.

Coal preparation may be physical or chemical (and biological). Physical cleaning is limited to nonchemical impurity removal, mostly washing to separate pyritic sulfur and mineral inclusions. Physical cleaning processes now in hand or in prospect are expected to remove up to 90% of the pyritic sulfur. Chemical cleaning, including the use of biological agents, is more challenging. Organic sulfur removal has remained a particularly tough problem, but

Pressurized fluidized-bed combustor produces low-Btu gas



there have been some encouraging results. Even though the work is still in the early stages, DOE is hoping that up to 90% of organic sulfur will be removable by appropriate chemical cleaning technology.

The object of using coal in boilers is to extract the maximum amount of heat. This usually means burning the coal at a temperature of about 2700 °F. This temperature is regularly achieved with conventional equipment. Advanced combustion equipment is supposed to do this with the addition of SO_x and NO_x control and the removal of particulate matter. The means to do this include the appropriate control of operating variables in the furnace and the introduction of sorbents.

A great variety of systems have been proposed. Some remove SO_x, some remove NO_x, some remove both. Depending on the technical details, up to 70% of NO_x emissions and 95% of SO_x emissions are expected to be removed routinely with advanced combustion technology now under development. Fluid-bed combustion is one of the more promising techniques under investigation.

Pollutants remaining after combustion must be removed downstream of the combustion zone. The usual method at present is the limestone scrubber, which can remove up to 90% of the SO_x but also causes corrosion problems and requires disposal of the sludge. More advanced systems are under development. These include injection of sorbents directly into the existing furnace ductwork or into separate vessels added for this purpose downstream from the firebox. Among the advantages of these systems are the possibility of regenerable sorbents, reduced size, and a benign waste product. They are expensive, however.

One of the more attractive technologies in the clean-coal program is combined-cycle processing in which coal, steam, and oxygen (or air) are combusted to produce fuel gases. The fuel gases are then cleaned and further burned and expanded in a turbine to generate the electric power. Any residual heat may be extracted to generate low-level steam. The great problem is getting the fuel gases clean enough to pass through the turbines without fouling them. The turbine cannot accept appreciable levels of impurities.

Another technology is mild gasification in which the volatile gases from the coal are driven off, leaving behind a char. Gases, the char, and occasional liquids are all valuable fuels and/or feedstocks.

Liquefaction of coal may be direct or indirect, depending on whether synthesis gas is produced. Converting the coal to synthesis gas permits the subsequent employment of such processing as the well-established Rölen, oxo, Fischer-Tropsch, and related chemistries. In recent years, there has been a surge of interest in C_1 chemistry, which employs carbonylation, hydroformylation, and other reactions. This may be revived in the event of another oil production crisis. The principal practitioner of this form of liquefaction is Sasol Technology Pty in South Africa, which utilizes local coal sources to produce that nation's fuel requirements.

Direct liquefaction is the conversion of coal, directly, to liquid fuels via hydrotreating to increase the hydrogen-to-carbon ratio of the hydrocarbons. Coprocessing is a variant of this technology, in which coal and heavy petroleum residues are processed together.

Congress has appropriated a total budget of about $2.75 billion for the five phases of the clean-coal program. The projects in the program are being cofunded by the private sector and DOE. The DOE share amounts to about 38% of the total. The general rule is that the private sector must contribute at least 50% of the total cost. If a project is successful, the government's contribution must be repaid from the profits.

Individual projects of the clean-coal program range from simple conceptual designs to extremely elaborate, full-size demonstration plants. The nature of the projects may be typified by the example of gas reburning and the simultaneous reduction of NO_x and SO_x with sorbent injection.

Gas reburning is a postcombustion technology that is being developed primarily for reduction of NO_x. Up to 85% of the fuel is coal, with the remainder being natural gas or other hydrocarbon fuels. The remainder bypasses the main combustion zone and is injected above the main burners to form a reducing zone in which the NO_x is converted to elemental nitrogen. A finely divided calcium sorbent is injected above the burn zone of the combustor. The expectation is that 60% of the NO_x and 50% of the SO_x will be removed by this technology, even using high-sulfur Illinois coal.

Another project that is related to but distinct from the clean-coal program is a second-generation pressurized fluidized-bed combustor being developed by private concerns under contract with DOE. They include Foster-Wheeler Energy Corp., the Institute of Gas Technology, Gilbert/Commonwealth Inc., Westinghouse Power Generation Business Unit, and Westinghouse Science & Technology.

The pressurized fluidized-bed combustor is a combustion unit intended for use by electric utilities. The intent is to increase generating efficiency with reduced costs despite the necessity of simultaneously reducing emissions and burning high-sulfur coal. The R&D effort is divided into three phases. The first is already complete, the second is now under way, and the third is yet to

Clean-coal program in midst of five-phase effort

Subprogram (phase)	Financial status ($ thousands) Enacted budget	Obligations to date	Costs to date
CCP-I	$ 387,231	$118,485	$ 94,919
CCP-II	535,707	76,753	27,677
CCP-III	545,546	25,636	250
CCP-IV	567,813	0	0
CCP-V	567,813	0	0
SBIR	32,963	14,139	14,139
Program direction	110,527	36,663	31,117
TOTAL	$2,747,600	$271,676	$153,963

Note: CCP = Clean-coal program, SBIR = Small Business Initiative Research program. Source: U.S. Department of Energy

Magentohydrodynamics and coal-fired power

Researchers are currently in the third year of a five-year proof-of-concept program on magnetohydrodynamics (MHD), a technique that promises to increase considerably the efficiency of coal-fired power generation. The Department of Energy-funded program will help utilities decide whether to proceed with design and construction of a prototype MHD retrofit plant.

In the MHD process, coal is burned at unusually high temperatures, creating an electrically conducting plasma. After enhancement of its conductivity by addition of a potassium salt (or "seed"), the plasma is directed through a magnetic field within an MHD channel. This produces direct current electric power, which is converted to alternating current for use in the electrical power grid. Because plasma gases leave the MHD channel at a relatively high temperature, they also are used to generate steam for conventional turbine power generation.

In the long term, MHD power plants are projected to be able to convert coal to electricity with efficiencies ranging from 50 to 60%, compared with efficiencies of about 35% for conventional coal-fired power plants. In addition, MHD would provide impressive environmental benefits in terms of reduced emissions of carbon dioxide and other pollutants. The seed material added to the plasma reacts with oxides of sulfur, removing them from the gas stream. In recent tests of an MHD system, more than 95% of sulfur pollutants released from burning high-sulfur coal were captured by the process. Other pollutants, such as nitrogen oxides and particulates, also can be maintained at low levels in the MHD process.

The five-year proof-of-concept program, administered by the Pittsburgh Energy Technology Center (PETC), includes tests on prototype MHD components and on use of MHD exhaust gases for steam generation and preheat of oxidizer gas. These two projects, along with others on regeneration of seed material and MHD retrofit plant design, are intended to prove the feasibility of the concept by the end of 1993. MHD research is also being conducted overseas, in countries that include the U.S.S.R., China, Japan, Poland, Italy, and India.

In the U.S., political support for R&D on the technology is strong, both in Congress and in states where the research is being conducted. For example, $50 million to help defray the cost of an MHD demonstration unit was recently appropriated by the state of Montana.

PETC administrators are optimistic about MHD, pointing out that the technology has shown continuous progress over the years. One MHD project manager says, "The potential for efficiency is unbeatable, and it could almost fly on the environmental attributes alone."

Stu Borman

come. The completed first phase included conceptual design, investigating plant sensitivity to variations in feedstocks and sorbents, preparation for commercialization, and other tasks. The second phase, now in progress, consists of a test program for several components and the analyses of these components and of the test results to establish baseline design data. The final phase will include construction of a 5-MW (electric) system, its evaluation in service, and necessary revisions of the baseline design.

In the plant, the coal is fed to a pressurized carbonizer that produces a low-Btu fuel gas and char. The fuel gas passes through a cyclone and cross-flow filter to remove particulates, which are then burned in a topping combustor to produce the energy required to drive the turbine. The turbine, in turn, drives a compressor and generator that feeds air to the carbonizer, a circulating pressurized fluidized-bed combustor, and a fluidized-bed heat exchanger. The char is burned in the fluidized-bed combustor with excess air. The depleted air from the combustor supports combustion of the fuel gas in the topping combustor. Steam from the heat recovery system drives the steam turbine generator that provides the rest of the electric power from the plant.

The low-Btu gas is produced in the carbonizer by pyrolysis and devolatilization of the coal in a fluidized-bed reactor. Because it operates at low temperatures, this unit also produces residual char. The fuel gas must be treated for removal of sulfurous components by injection of lime-based sorbents into the carbonizer. The sulfur from the hydrogen sulfide and tars is captured thereby as calcium sulfide. Sulfur is captured in situ, thus eliminating the need for downstream heat exchangers and special sulfur recovery apparatus.

Char and calcium sulfide entrained in the fuel gas are removed in a high-temperature filter. The resulting fuel gas is, essentially, particle free. The particulate matter is injected back into the pressurized fluidized-bed combustor.

Based on preliminary data from the first phases, it appears that the second-generation pressurized fluidized-bed plant operates at about 45% efficiency, and the electricity cost is about 22% lower than with a comparable conventional plant.

At a recent technical conference on the problems of energy production and use, a veteran engineer observed that about every 10 years or so the government appears with a new program that reinvents the coal-fired boiler in a new form. He is convinced that the clean-coal program is the latest example. While there is no doubt that the repeated efforts will eventually get something done, he is also of the opinion that faster progress is possible by simply letting the industry alone long enough to "do its own thing." The example he favored was that of the Texaco gasification process, which was developed for synthesis gas production but has found many other applications.

Not all agree with this opinion. The opposing viewpoint is that to manage progress in an era of hyperregulation and environmental threat, it is necessary simultaneously to appease the special interest advocates. It isn't enough to merely progress. It must be done with the protocol of the pork barrel and the media blitz. □